ACCURATE CONTROL OF TRANSMISSION INFORMATION
IN AD HOC NETWORKS

FIELD OF THE INVENTION

The invention relates to the accurate control of
transmission information in ad hoc networks, for example to
the monitoring of packet transmission for an accurate
accounting in ad hoc networks. More specifically, the
invention relates to a gateway for forwarding transmission
information between a first terminal node of a first
network and a second terminal node of an ad hoc network, a
terminal node of such an ad hoc network and a communication
system comprising said first network with at least a first
terminal node, said ad hoc network with at least second
terminal node, and said gateway. The invention also relates
to a method for forwarding transmission information between
said first terminal node and the second terminal node of
the ad hoc network.

As will be explained below with more details, one
application area of ad hoc networks is the extension of
existing cellular networks, in particular, mobile devices
of private users can be used to relay data between the
sending/receiving device and for example the base station
of the cellular network. An intrinsic property of such ad
hoc networks is that the network itself is only established
"ad hoc", i.e. when needed or requested by particular
private users. In this scenario mobile devices of other
user may be used "ad hoc" to just relay data between the

actual end device and the base station of the cellular
network.

In such "ad hoc" configured networks, transmission
information is typically forwarded from a gateway, e.g. a
base station, to a terminal node of the ad hoc network
through other relaying nodes. Whilst the gateway can
prescribe a particular route through relaying nodes to the
receiving terminal node, due to congestion or other
problems along this route, the transmission information
from the gateway might also be routed through other
relaying nodes. The problem of how to find out which route
the actual transmission information took in the ad hoc
network is addressed in our parallel application
PCT/EP03/02241.

However, even if the route taken by the transmission
information can be established, there still exists the
problem in ad hoc networks that the gateway simply forwards
the transmission information to the relaying nodes of the
ad hoc network without knowing whether the transmission
information has actually reached the intended end terminal
node. For example, the end terminal node may be switched
off or the information transmission might have gone lost
along the route due to failures of the wireless links.
Thus, the gateway might carry on sending transmission
information to this particular end terminal node whilst
none of the transmission information has actually reached
said node.

Hence, the gateway has no mechanisms to perform an accurate
flow control of the transmission information in the ad hoc
network. It is this problem which is addressed by the
present invention.

The aforementioned problem of lack of flow control in the gateway – when forwarding transmission information to the end terminal node of the ad hoc network – becomes particularly apparent when considering an accurate accounting for the forwarding of the transmission information. Since for the establishment of an ad hoc network there should be an incentive for users to provide their devices as relaying devices because the relaying itself consumes memory, processing power and battery power, an accurate accounting is of particular importance in such ad hoc networks. However, since ad hoc networks are basically established within the frame work of mobile communication networks, the accounting is still done in the gateway by merely considering the sent out transmission information without having any information about the question whether the data actually arrived at the end terminal node. Henceforth, the gateway might charge the end terminal node for transmission information which has been sent out but which has never reached the end terminal node. Thus, the accurate accounting is one of the problems which is addressed with the aim at providing an accurate flow control by the gateway.

BACKGROUND OF THE INVENTION

As already mentioned above, the present invention aims at providing a more accurate flow control for the forwarding of transmission information in ad hoc networks. Hereinafter, some basic functionalities of ad hoc networks will be explained with reference to Fig. 1 and Fig. 2. Further information about ad hoc networking can be found from "Wireless ad hoc networking – the art of networking without a network" by Magnus Frodigh et al. in Ericsson Review, No. 4, 2000, pages 248-263.

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Fig. 1 shows a typical scenario at an airport where people
can access local- and wide-area networks, for example
through an WCDMA indoor base station BS and a HiperLan/2
access point AP. Fig. 1 also shows typical nodes of the ad
hoc network, for example a first node MN1 formed by a
personal area network of a notebook computer NC1 connected
through a Bluetooth Connection to a personal digital
assistant PDA1. Another node RN2 might consist of a
personal area network PAN only formed by a mobile telephone
MT2 and a personal digital assistant PDA2. The node MN3 is
yet formed by another network of a personal digital
assistant PDA3, a mobile telephone MT3 and a notebook
computer NC3. However, a node like MN4 might simply be
formed by a single mobile telephone MT4. Thus, in Fig. 1
user's devices can both interconnect with one another and
connect the local information points - for example, to
retrieve updates on flight departures, gate changes and so
on. Thus, in Fig. 1, for example the node MT4 and the node
MN1 might directly access information from the base station
BS. For example, a user might retrieve e-mail via a
HiperLan/2 interface to a notebook computer in a briefcase,
but read messages and reply to them via his or her personal
digital assistant PDA1, PDA3.

On the other hand, node MT4 might not only directly be
connected to the mobile telephone MT2 through the base
station BS but by using the node MN1 as a relaying node,
i.e. the node MN1 can be used to relay traffic to the node
RN2 through Bluetooth Connections which are only
established "ad hoc", i.e. not permanently. This relaying
of transmission information is known as "single or multiple
radio hop architecture", i.e. transmission information from
a node outside the ad hoc network might be transmitted to
the end terminal node (e.g. RN2) through one (singe hop) or
more (multiple hop) other ad hoc nodes.

Such a scenario is further illustrated in Fig. 2 with four
interconnected nodes RN1, RN2, RN3, MN1 wherein two nodes
RN1, RN3 have an internet connection via a Bluetooth LAN
access point and a GPRS/UMTS phone respectively through a
GPRS network GN and two routers RT. Clearly, if for example
a terminal node connected to the internet or corporate IP
network IN sends transmission information directed to the
end terminal node MN1, the nodes RN1 and RN2 will act as
relaying nodes which forward the transmission information
through communication routes which are only set up on
request, i.e. "ad hoc". As shown in Fig. 2, one of the
perhaps most widespread notions of the mobile ad hoc
network is that the network is formed without any central
administration and consists of mobile nodes that use a
wireless interface to send transmission information.

It should also be noted that of course there is no need
that the relaying nodes and the end terminal node are in
close vicinity to each other, i.e. the ad hoc devices can
also relay traffic between devices that are out of range.
In addition, since the ad hoc network is based on for
example a wireless mobile communication system the mobile
devices move around (mobility) and thus the "ad hoc" i.e.
spontaneously formed network might be spread out over large
distances.

Furthermore, provided that a node is registered as an ad
hoc node, the ad hoc nodes will use spontaneously assigned
ad hoc addresses rather than globally fixed addresses.
Thus, one of the central aspects of ad hoc networks is that
these are formed spontaneously ("ad hoc") amongst the
devices which are registered as ad hoc nodes. Rather than
administered by a central facility, the ad hoc nodes will
establish communication connections such as a wireless
Bluetooth Connection, on demand and by themselves.

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Since the ad hoc nodes themselves establish connections
amongst each other in an ad hoc, i.e. spontaneous way, thus
increasing the coverage of existing base stations without
requiring additional hardware, users need an incentive for
providing their devices for the relay service. One possible
incentive is that the users get a reward for the relaying
service and only the end terminal node is charged for
receiving the transmission information just like in
conventional mobile networks. However, even if there is
provided a gateway GW providing the connection to the first
network IN, the gateway GW has no information whether a
particular relaying node has relayed transmission
information and/or whether the end node has actually
received any transmission information. Thus, there is no
actual accurate flow control or traffic information
monitoring of the transmission information forwarding
between the nodes of the ad hoc network. For example, the
charging accounting for information transfer within the ad
hoc network can only be based by using a mechanism in the
gateway GW which accounts for the forwarded transmission
information.

This problem is further illustrated with reference to Fig.
3a, 3b which shows the typical communication system SYS
considered by the present invention. The communication
system SYS includes a first network IN with a least first
terminal node CN (hereinafter also called the corresponding
node), an ad hoc network AHN with at least a second
terminal node RN1-RN4, MN and a gateway GW for forwarding
transmission information TI between the first terminal node
CN of said first network IN and said second terminal node
RN1-RN4, MN of said ad hoc network AHN. Each node CN, RN1-
RN4, MN has a corresponding transmission/reception unit
TRC, TR4, TRN and also the gateway GW itself has such a
transmission/reception unit TRG. The transmission/reception
unit TRN is adapted to receive transmission information TI

from the other terminal CN through the gateway GW either
through the main route MR or through an alternative route
AR which is set up as wireless connections between the
individual ad hoc nodes RN1, RN2, RN3. Each of the nodes
RN1-RN4, MN also has a routing means, e.g. RM4 and RMN, for
achieving the relaying function as described above. The
first terminal node CN has a global source identifier
(global source address) SAC and each of the ad hoc nodes
RN1-RN4, MN have a corresponding target address, e.g. TA4,
TAN. In the transmission information memory TIS of the
first terminal node CN information such as a destination
address for the transmission information is stored. The
transmission information TI sent out from the first
terminal node CN is received by the transmission/reception
unit TRG of the gateway GW and is then transmitted to the
second terminal node RN1-RN4, MN. The first network IN is
any kind of an operator-controlled network, for example the
Internet or a mobile communication network. The gateway GW
can be an access point or a base station. Not necessarily
does the gateway GW belong to the ad hoc network. That is,
the gateway GW is merely to form the interface between the
corresponding node CN and the nodes of the ad hoc network.
Thus, the ad hoc network AHN consists for example of a
mobile node MN that is sending and receiving data and
several candidate relaying nodes RN1-RN4. The corresponding
node CN can be located anywhere outside of the ad hoc
network, not necessarily in the operator-controlled
network. In this scenario, the node MN could transmit data
over RN2, RN1 and GW to the corresponding node CN.
Furthermore, it is assumed that users of all mobile devices
have a contract with the cellular network operator.

Fig. 3a also shows an accounting unit ACC adapted to
determine charging information CH for the transmission of
the transmission information TI to the second terminal
node. For determining the charging information CH, the

accounting unit ACC may determine the charging information
CH on the basis of some transmission characteristics TCH
determined by a transmission information characteristics
determining unit TIM. These transmission characteristics
TCH can also be stored in the transmission information
memory TIS, as shown in Fig. 4a. If for example the
determined transmission characteristics TCH comprise a data
amount DAM and a transmission speed TRT, the accounting
means ACC can determine a charging information CH of 7 Cent
for the forwarding of transmission information of 2MB with
a transmission rate of 64 kbit/s to the target node RN4
having the target address TA. Thus, with a data set as
shown in Fig. 4a in the transmission information memory
TIS, it is easy for the accounting unit ACC to provide some
kind of accounting for the downlink (from corresponding
node CN to the target ad hoc node).

For uplink transmission information (for example from the
ad hoc mobile node MN to the corresponding node CN through
the gateway GW), it is obvious that the gateway GW only
receives and charges/rewards transmission information which
did not get lost. Thus, in the uplink direction the gateway
GW can always perform some kind of accurate accounting.

However, problems arise regarding the accurate flow control
or accurate accounting regarding the downlink transmission
information. Actually, users should only be charged and
rewarded for transmission information that they actually
have transmitted and should only be charged for
transmission information which they actually have sent or
received. However, since the gateway GW has no information
whatsoever what happens to the transmission information TI
after it has been sent out by the transmission/reception
unit TRG of the gateway GW, the accounting unit ACC can
only make a guess whether or not the transmission
information has actually reached the desired ad hoc and

terminal node, e.g. MN. This is generally true, not only
for the specific example of having to provide an accurate
accounting. Namely, the gateway GW can generally transmit
transmission information but it has no actual control over
it because no further information about the possible
arrival or non-arrival of the transmission information is
available. Therefore, the gateway GW can not generally
perform any other accurate control (flow control) of the
transmitted transmission information.

For example, as shown in Fig. 3b, if there is a cut-off of
a wireless link along the main route MR between two
relaying nodes RN1, RN2, then the gateway GW has no
possibility to know whether or not the transmission
information TI has actually arrived at the second terminal
node MN. Thus, the gateway GW, i.e. its transmission
information memory TIS can only store information about all
transmission information which it has sent to the second
terminal node MN in order to perform proper charging and
rewarding. However, the entire accounting is intrinsically
based on the assumption that the entries in the
transmission information memory TIS reliably relate to a
transmission information which has actually reached the
second terminal node. If not, as shown in Fig. 3b, the
mobile end node MN would be charged for transmission
information which has not been successfully delivered.

On the other hand, the user of the second end terminal node
MN might simply contest that it has received any
transmission information, even if it has arrived, in order
not to be charged by the gateway GW. In such a scenario,
the gateway GW has no means to verify and to demonstrate to
the second terminal node MN that the transmission
information TI has actually arrived and that the charging
information CH is accurate. Since the gateway GW has no
evidence that the transmission information TI has actually

arrived at the second terminal node MN, despite the fact
that the transmission information TI has arrived, a
misbehaving second terminal node MN might achieve that it
does not have to pay for the transmission information which
it actually has received.

It should be noted that the above described problem of
accurate accounting is only one sub-problem of the general
problem that the gateway GW cannot provide an accurate flow
control of the packets. For example, also other flow
control mechanisms in the gateway GW might require accurate
knowledge about the fact whether or not the transmission
information TI has actually arrived at the desired target
terminal node MN. For example, another flow control for the
transmission information TI could involve the increase or
decrease of transmission rate or the complete stoppage of
transmitting transmission information TI if it was known
that one of the wireless links on the main route MR or the
alternative route AR has failed.

Another example of insufficient flow control is the
occurrence of a congestion on the main route MR or
alternative route AR which calls for a reduction of
transmission rate. However, in conventional ad hoc networks
the gateway GW has no possibility of detecting any reasons
of loss of transmission information, such as noise,
congestion or misbehaviour of users/devices.

SUMMARY OF THE INVENTION

As explained above, a conventional gateway GW and a
conventional terminal node RN1-RN4, MN are deficient
because they do not allow an accurate control of
transmission information in the ad hoc network. For
example, an adaptation of flow control parameters, such as
transmission rate, transmission amount, as well as an
accurate accounting is not possible in conventional ad hoc

networks. The present invention aims at avoiding these
disadvantages.

Specifically, it is an object of the present invention to
provide a gateway, a terminal node of an ad hoc network,
communication system as well as a method in an ad hoc
network which respectively allow an accurate flow control
of transmission information within the ad hoc network.

This object is solved by a gateway for forwarding
transmission information between a first terminal node of a
first network and a second terminal node of an ad hoc
network, comprising:
a transmission/reception unit adapted to receive
transmission information from said first terminal node and
to transmit said transmission information to said second
terminal node; and
an acknowledgment information detection unit adapted to
detect the receipt of acknowledgment information from said
second terminal node acknowledging that said second
terminal station has received said transmission
information.

Furthermore, this object is solved by a terminal node of an
ad hoc network for exchanging transmission information with
another terminal node of another network (IN) connected to
said ad hoc network through a gateway, comprising: a
transmission/reception unit adapted to receive transmission
information from said another terminal node through said
gateway; and an acknowledgment information transmission
unit adapted to transmit to said gateway acknowledgment
information acknowledging that said transmission/reception
unit has received said transmission information.

The object is also solved by a communication system
including a first network with at least a first terminal

node, an ad hoc network with at least a second terminal
node, and a gateway for forwarding transmission information
between said first terminal node of said first network and
said second terminal node of said ad hoc network, wherein
said gateway is constituted in accordance with on or more
of claims 1 to 29 and wherein said second terminal node is
constituted in accordance with one or more of claims 30 to
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The object is also solved by a method for forwarding
transmission information between a first terminal node of a
first network of a communication system and a second
terminal node of an ad hoc network of said communication
system, comprising the following steps in a gateway of said
communication system: receiving, in said gateway of said
communication system, transmission information from said
first terminal node and transmitting, from said gateway,
said transmission information to said second terminal node;
detecting (S5c5), in said gateway, the receipt of
acknowledgment information from said second terminal node
acknowledging that said second terminal station has
received said transmission information.

The object is also solved by a method for forwarding
transmission information between a first terminal node of a
first network of a communication system and a second
terminal node of an ad hoc network of said communication
system, comprising the following steps in said second
terminal node:
receiving, in said second terminal node transmission
information from a gateway of said communication system;
and
transmitting, from said second terminal node, to said
gateway acknowledgment information acknowledging that said
second terminal node has received said transmission
information.

Furthermore, the object is also solved by a method for
forwarding transmission information between a first
terminal node of a first network of a communication system
and a second terminal node of an ad hoc network of said
communication system, comprising the following steps in
said communication system: receiving, in a gateway of said
communication system, transmission information from said
first terminal node and transmitting, from said gateway,
said transmission information to said second terminal node;
receiving, in said second terminal node, said transmission
information from said gateway; transmitting (S5c4), from
said second terminal node, to said gateway acknowledgment
information acknowledging that said second terminal node
has received said transmission information; and detecting,
in said gateway, the receipt of said acknowledgment
information from said second terminal node acknowledging
that said second terminal station has received said
transmission information.

An accurate flow control of the transmission information in
the ad hoc network is possible in accordance with the
invention, as defined above, because there is provided
reliable information (acknowledgement information)
indicating whether transmission information has reached the
end terminal node or not. Furthermore, another advantage is
that a misbehaviour of the second terminal node receiving
the transmission information is inhibited because it is not
possible for the second terminal node any longer to receive
the transmission information without being charged for it.

The provision of accurate flow control of transmission
information within the ad hoc network provides several
advantages for example in connection with embodiments
directed to an accurate accounting. For example, the
accounting unit may be adapted to determine charging
information for the transmission of said transmission

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information to said second terminal node if said
acknowledgment information detection unit detects the
receipt of acknowledgment information for the transmission
of said transmission information to said second terminal
station. Thus, the end terminal node is only charged for
acknowledged transmission information.

If in accordance with claim 7 the second ad hoc network is
a packet switched network, the transmission information
comprises one or more transmission packets and said
acknowledgement information comprises one or more
acknowledgement packets, a transmission characteristics
determining unit in accordance with claim 8 is adapted to
determine the transmission characteristics for each
acknowledged transmission package of the transmission
information. Thus, an accurate accounting and charging is
possible on a packet by packet basis.

Particularly advantageous is if said gateway comprises a
sequence number insertion unit adapted to insert into each
transmission packet a sequence number indicating the
transmission order of the respective transmission packet in
a sequence of transmission packets. Preferably, also said
terminal node comprises a sequence number determining unit
adapted to determine in each received packet a sequence
number indicating the transmission order of the respective
transmission packet in a sequence of transmission packets;
wherein said acknowledgment information transmission unit
is adapted to transmit to said gateway acknowledgment
packets respectively containing the detected sequence
number of the received packet whose receipt is to be
acknowledged with said respective acknowledgment packet.
Thus, the gateway not only receives an acknowledgement
information indicating that transmission information in
general was received but an acknowledgement information
which acknowledges particular transmission packets. Thus,

the accuracy in the accounting or in the flow control may
be further enhanced because the gateway has detailed
information about the individual packets that have received
the end terminal node.

It is further advantageous to provide in the gateway a
transmission window unit adapted to set a predetermined
transmission window for said transmission/reception unit to
successively transmit transmission packets to said second
terminal node; wherein said transmission/reception unit is
adapted to successively transmit to said second terminal
node transmission packets within said transmission window;
and wherein said transmission/reception unit is adapted to
slide said transmission window one or more packets to form
a new transmission window and to successively transmit to
said second terminal node one or more successive
transmission packets within said new transmission window
which have not already been transmitted in the previous
transmission window whenever the receipt of an
acknowledgment packet, acknowledging the receipt of a
transmission packet of the previous transmission window, is
detected by said acknowledgment information detection unit.
The advantage is that here the acknowledgment packets are
accumulative, i.e. an acknowledgement with a certain
sequence number additionally acknowledges all preceding
packets (if the roundtrip time remains constant). If the
roundtrip time stays constant it is sufficient for an
accurate flow control if the gateway only receives the
acknowledgement packet for the transmission packet which
was the last one to be transmitted from the gateway within
the transmission window.

The present invention allows for a more accurate flow
control by the provision of the acknowledgement
information. However, it might still be the case that a
transmission packet and/or an acknowledgement packet gets

lost for some reason during the transmission to the gateway
and the second terminal node. Therefore, another embodiment
of the invention comprises a lost packet detector adapted
to detect that an acknowledgement packet or a transmission
packet has gone lost during its transmission if after
transmission of a predetermined number of transmission
packets in the transmission window set by said transmission
window unit, the sequence numbers in successive
acknowledgment packets do not match with those set in the
successive transmission packets.

Advantageously, the lost packet detector might comprise a
timer adapted to count a predetermined time duration, said
timer being started with each new transmission of a
transmission packet, being stopped if an acknowledgement
packet is received for the last transmitted transmission
packet within said predetermined time duration or ,if not
being stopped by the receipt of an acknowledgment packet,
said timer expiring, wherein said TRN stops transmission.

An acknowledgement request unit may advantageously be
provided, adapted to transmit to said second terminal node
an acknowledgment request packet including a predetermined
sequence number of a transmission packet which was
transmitted but for which no acknowledgement information
has as yet been detected by said acknowledgment information
detection unit, said acknowledgment request message
requesting from said second terminal node the transmission
of an acknowledgment packet acknowledging the receipt of
the transmission packet having said predetermined sequence
number.

Preferably, if said timer times out and no acknowledgment
information is detected by said acknowledgment information
detection unit within said time duration after transmission
of the last transmission packet in said transmission

window, said acknowledgment request unit is adapted to
transmit to said second terminal node an acknowledgment
request packet including the sequence number of the last
transmission packet transmitted in the transmission window.

Preferably, said timer is also started when said
acknowledgment request unit starts transmitting said
acknowledgment request package, wherein if said timer times
out thereafter and no acknowledgment information is
detected by said acknowledgment information detection unit
within said time duration after transmission of said
acknowledgment request package, said transmission/reception
unit stops transmission of further transmission packets.

Preferably, a route check unit is provided, adapted to
detect whether a transmission route to said second terminal
node exists.

Preferably, said transmission/reception unit stops
transmission of further transmission packets if after said
timer times out, said route check unit detects that no
transmission route exists.

Preferably, said transmission/reception unit is adapted to
retransmit an already transmitted transmission packet
having a specific sequence number in response to receiving
a retransmission request packet including said specific
sequence number from said second terminal node.

In a particularly advantageous embodiment of the invention
said transmission/reception unit comprises a first tunnel
setup unit for setting up a first tunnel link between said
gateway and said second terminal node, wherein said
transmission/reception unit transmits said transmission
information and receives said acknowledgment information to
and from said second terminal node respectively through

said first tunnel link. The tunnel will advantageously set
up a kind of fixed "logical" link between the gateway and
the second terminal node such that for example the entire
transmission of transmission packets and acknowledgement
packets always takes the same route through the relaying
nodes between the gateway and the second end terminal. The
usage of the first tunnel is also advantageous in cases
where the corresponding node and the ad hoc terminals do
not have the same format of addresses. Another advantage of
the tunnel set-up is that the packet from the corresponding
node remains intact, i.e. its format is not changed in the
gateway when it is transmitted through the tunnel to the
second terminal node.

Advantageously, said first tunnel setup unit sets up said
first tunnel link by encapsulating transmission packets
into modified transmission packets generated and
transmitted by said transmission/reception unit.

The first tunnel set-up unit is mainly provided to perform
the accurate flow control, for example for accounting
purposes. On top of the first tunnel another transport
protocol can be run. Therefore, advantageously, said
transmission/reception unit comprises a second tunnel setup
unit for setting up a second tunnel link encapsulated
within said first tunnel link between said gateway and said
second terminal node, wherein said transmission/reception
unit transmits said transmission information and receives
said acknowledgment information to and from said second
terminal node respectively by using said second tunnel link
encapsulated within said first tunnel link.
The advantage of using the second tunnel together with the
first tunnel is that the second tunnel may be based on a
protocol such as TCP, i.e. a non IP protocol, which allows
flow control such as the exchange of acknowledgements
whilst the first tunnel will then provide the IP routing.

Preferably, said second tunnel setup unit sets up said
second tunnel link by encapsulating transmission packets
received from said first terminal node into modified
transmission packets generated by said
transmission/reception unit; and
said transmission packets, which are encapsulated by said
first tunnel setup unit into said modified transmission
packets transmitted by said transmission/reception unit,
are said modified transmission packets encapsulated by said
second tunnel setup unit.

Preferably, said terminal node can comprise a packet
retransmission request unit adapted to transmit to said
gateway a retransmission request packet including a
sequence number of a transmission packet which is requested
to be retransmitted from said gateway.

Further advantageous embodiments and improvements of the
invention may be taken from the dependent claims.
Hereinafter the invention will be described with reference
to its advantageous embodiments with reference to the
drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Fig. 1   illustrates the principle of ad hoc networking in
            an airport scenario, in accordance with the prior
            art;

Fig. 2   shows a personal area network scenario with four
            interconnected ad hoc nodes two of which have an
            internet connection via a Bluetooth LAN access

point and a GPRS/UMTS telephone, in accordance
with the prior art;

Fig. 3a   shows a communication system SYS in which
           transmission information TI is transmitted from a
           first terminal node CN outside an ad hoc network
           AHN to a second terminal node MN inside the ad
           hoc network;

Fig. 3b   shows a packet lost scenario in the communication
           system SYS of Fig. 3b;

Fig. 4a   shows the contents of a transmission information
           memory TIS of the gateway GW shown in Fig. 3a;

Fig. 4b   shows the contents of a transmission information
           memory TIS' of a gateway GW in accordance with
           the invention;

Fig. 4c   shows a further embodiment of the transmission
           information memory TIS' in accordance with the
           invention, for the case of accounting for
           individual transmission packets IP1-IP5;

Fig. 5a   shows a principle overview of a communication
           system SYS with a gateway GW and a second
           terminal node MN in accordance with the
           invention;

Fig. 5b   shows a principle flow chart of the accounting
           method in accordance with an embodiment of the
           invention;

Fig. 5c   shows the principle message flow of the method
           for an acknowledgement transmission in the method
           shown in Fig. 5b;

Fig. 6   shows the principle block diagram of a gateway GW
            and a second terminal node RN, MN in accordance
            with the invention;

Fig. 7   shows the insertion of sequence numbers and the
            transmission of transmission packets IP1-IP5 and
            acknowledgement packets ACK1-ACK5 with reference
            to a transmission window, in accordance with one
            embodiment of the invention;

Fig. 8   shows a similar flow chart as in Fig. 7, for the
            case of a lost acknowledgement package, in
            accordance with one embodiment of the invention;

Fig. 9   shows a flow chart similar as in Fig. 7, for the
            case of a lost transmission packet IP2, in
            accordance with another embodiment of the
            invention;

Fig. 10   shows an embodiment of using a timer T in
            connection with the transmission of transmission
            packets within a transmission window WIN;

Fig. 11   shows a flow chart using a timer T and the
            sending of an acknowledgement request packet
            SOL_ACK3, in accordance with another embodiment
            of the invention;

Fig. 12   shows the case of a transmission stop when using
            the timer T and the acknowledgement request
            packet SOL_ACK3, in accordance with another
            embodiment of the invention;

Fig. 13   shows a message flow for the case of performing a
            route check before sending the acknowledgement
            request packet SOL_ACK3;

Fig. 14   shows the stoppage of the transmission in
             connection with a timer T and an interrupted
             route, in accordance with another embodiment of
             the invention;

Fig. 15   shows a message flow when the second terminal
             node MN actively requests the retransmission of a
             transmission packet from the gateway GW, in
             accordance with another embodiment of the
             invention;

Fig. 16   illustrates the principle of setting up a first
             tunnel TUN1 between the gateway GW and the second
             terminal node MN, wherein

Fig. 16a   shows the usage of global addresses and ad hoc
             addresses; and

Fig. 16b   shows the encapsulation of a transmission packet
             IPx from the first terminal node CN into a
             modified transmission packet IPxx on the first
             tunnel TUN1;

Fig. 17   shows the encapsulating of a second tunnel TUN2
             inside the first tunnel TUN1; and

Fig. 18   shows a protocol stack of using different second
             tunnel protocols UDP, L2TP, PPP on top of the
             first tunnel protocol IP.

In the drawings, the same or similar reference numerals are
used to designate the same or similar steps and features.
Whilst Fig. 6 shows a block diagram of the gateway GW and
the second terminal node RN, MN including in combination
different embodiments of the invention, on top of the Figs.

5c, and 7-15 the respective units are shown which are most responsible for respectively carrying out the functions and steps shown in the respective features. Therefore, it should be understood that the units shown in combination in Fig. 6 may also be used separately in accordance with the different embodiments of the invention.

PRINCIPLE OF THE INVENTION

Fig. 5a shows a principle overview of the communication system SYS to which the invention relates. The communication system SYS includes a first network IN with at least a first terminal node CN and ad hoc network AHN with at least a second terminal node RN1-RN5, MN and a gateway GW for forwarding transmission information TI between said first terminal node CN of said first network IN and said second terminal node of said ad hoc network AHN. Hereinafter, the first terminal node will also be called the corresponding node CN, as shown in Fig. 5a. Furthermore, it should be noted that the first network IN can be any kind of operator-controlled network, for example the Internet or any mobile communication network. The ad hoc network AHN may be any kind of network formed in accordance with the principles of ad hoc networking as outlined above. That is, the ad hoc network comprises ad hoc nodes RN1-RN4 which can act as relaying nodes and one node MN is shown to be the receiving node for the transmission information TI. Any kind of ad hoc routing link can be used, for example Bluetooth Connections or typically other wireless links. However, the establishment of the ad hoc network is not restricted to any specific kind of communication connections and comprises all communication connections for setting up an ad hoc network spontaneously as described above.

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The second terminal node MN and the relaying nodes RN1-RN4
can be any kind of devices as long as they allow a relaying
of transmission information. Examples for the relaying
nodes are a mobile telephone, a notebook computer, a
personal digital assistant, a laptop computer etc. Examples
of the gateway GW comprise a base station BS or an access
point AP, for example a WCDMA indoor-based station BS and a
HiperLAN/2 access point, as shown in Fig. 1.

Furthermore, although hereinafter many principles of the
embodiments of the invention will be explained below with
reference to packet transmission inside the mobile ad hoc
network AHN, it should be noted that many embodiments of
the invention are not restricted to a packet transmission
inside the mobile ad hoc network AHN. It is also
perceivable that the ad hoc network is set up by
establishing for example wireless radio links by means of
other transmission methods such as OFDM or TDM.

Comparing the communication system SYS of Fig. 5a with the
conventional communication system SYS of Fig. 3a, it
becomes clear that the gateway GW and the second terminal
node MN, in addition to a respective transmission/reception
unit TRG and TRN, respectively, also comprise an
acknowledgement information detection unit ACKM in the
gateway GW and an acknowledgement information transmission
unit ACKSN in the second terminal node MN. The
acknowledgement information detection unit ACKM is adapted
to detect the receipt of acknowledgement information ACTAN,
ACTAN', ACTAN'' from said second terminal node MN. The
acknowledgement information ACTAN, ACTAN', ACTAN''
acknowledges that the second terminal station MN has
received said transmission information.

On the receiving node MN side, the acknowledgement
information transmission unit ACKSN is adapted to transmit

to the gateway GW said acknowledgement information ACTAN,
ACTAN', ACTAN'' acknowledging that the
transmission/reception unit TRN of the second terminal node
MN has received the transmitted transmission information
TI, TI', TI''. That is, in accordance with one principle of
the invention each transmission of downlink transmission
information TI, TI', TI'' to the second terminal MN is
acknowledged with an acknowledgement information from the
second terminal node, as shown in Fig. 5c. Thus, an
accurate flow control can be performed in the mobile ad hoc
network AHN. For example, now the gateway GW always has
certified information that actually the downlink
transmission information has arrived at the second terminal
node MN or - when no acknowledgement is sent - that there
has been a problem such as congestion, lost package or
misbehaviour of users/devices - inside the ad hoc network.
Thus, the flow control in the ad hoc network AHN can be
improved.

Preferably, the forwarding of the transmission information
and acknowledgement information between the gateway GW and
the second terminal node MN (or more precisely between
their transmission/reception units TRG and TRN,
respectively) is performed through a security association
(trust relationship) between the gateway GW and the second
terminal node MN. Trusted relationship or security
association, in this context, means standard authentication
procedures such that for example the second terminal nodes
RN1-RN4 and MN will trust each other that they will always
relay packets or transmission and acknowledging information
if they are registered to become ad hoc terminal nodes of
an ad hoc network. Furthermore, also the relaying nodes
RN1-RN4 should preferably have such a trusted relationship
with the gateway GW or amongst themselves because they
likewise need to be charged or rewarded when receiving or
relaying information. The build-up of trust relationships

or authentication procedures as such is well known in the
art of mobile communication technology and does not need
further explanation here.

Fig. 5c shows for the gateway side GW and the second
terminal node side MN the respective steps carried out in
accordance with the principle method of the invention. In
step S5c1 the gateway GW of said communication system
receives the transmission information TI from the first
terminal node CN. In step S5c2 the transmission/reception
unit TRG transmits the transmission information TI to the
second terminal node MN after for example having built up
the trusted relationship (security association).

In step S5c3 the transmission/reception unit TRN of said
second terminal node MN receives the transmission
information TI from the gateway GW. In step S5c4 the
acknowledgement information transmission unit ACKSN
transmits to the gateway GW the acknowledgement information
ACTAN which acknowledges that the second terminal node MN
has received the transmission information TI. In step S5c5
the acknowledgement information detection unit ACKN of the
gateway GW detects the receipt of the acknowledgement
information ACTAN and can now safely assume that the second
terminal node MN has received the transmission information
TI.

Using the acknowledgement information ACTAN, ACTAN',
ACTAN'', the gateway GW can perform an accurate flow
control of information inside the ad hoc network AHN. For
example, if there is a delay or congestion along the main
route MR or the alternative route AR resulting in a delayed
transmission of the acknowledgement information, the
gateway GW can for example adjust the transmission rate
etc. depending on the transmission characteristics. The
more accurate flow control is particularly advantageous for

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performing an accurate accounting for the transmission
information on the downlink connection between the gateway
GW and the second node MN.

IMPROVED ACCOUNTING EMBODIMENT

Fig. 6 shows an accounting unit ACC' as being part of the
gateway GW. This accounting unit ACC' is used in the
principle flow chart of the accounting method in accordance
with an embodiment of the invention as shown in Fig. 5b.
Fig. 4b shows the contents of a transmission information
memory TIS' of the gateway GW in accordance with the
invention and Fig. 4c shows the contents of the
transmission information memory TIS' for the case of packet
transmission between the gateway GW and the second node MN.

More specifically, the accounting unit ACC' is adapted to
determine charging information CH for a transmission of the
transmission information TI, TI' TI'' to the second
terminal node MN if said acknowledgement information
detection unit ACKM detects the receipt of acknowledgement
information ACTAN, ACTAN', ACTAN'' for the transmission of
said transmission information to said second terminal
station MN. As can be seen from Fig. 4b, in addition to the
source address SA, the transmission data amount DAM, the
transmission rate TRT (or the transmission timing), the
target address TA and the charging information CH, the
transmission information memory TIS' in accordance with one
embodiment of the invention also comprises an entry for the
acknowledgement information (in Fig. 4b designated with
ACTA4, ACTAN). That is, the accounting unit ACC' in
accordance with one embodiment of the invention only
performs a calculation of transmission information charges
CH and performs a charging of the second terminal node MN,
if an actual acknowledgement information ACTA4, ACTAN has
been received from second terminal node MN. Thus, it is

avoided that on the one hand the second terminal node MN is
charged for transmission information TI, TI', TI'' which
has actually not reached the second terminal node MN, and
on the other hand, the gateway GW could decide to only send
further transmission information TI', TI'' if for a first
sent transmission information TI a corresponding
acknowledgement has been received. For example, a
misbehaving node might indeed have received the
transmission information TI but may decide not to transmit
the acknowledgement information ACTAN in order to avoid
being charged for the reception of the transmission
information TI. However, if the gateway GW, i.e. its
transmission/reception unit PRG, decides to discontinue the
transmission of further transmission information unless an
acknowledgement is received, it can be avoided that further
transmission information is sent to misbehaving nodes.

Fig. 5b shows an example of a flow chart of an accounting
method in accordance with one embodiment of the invention.
On the left-hand side the respective functions of the
accounting on the gateway GW side are shown and on the
right-hand side the respective functions of the second node
MN are shown.

In Step S51 the gateway GW, i.e. its
transmission/reception unit TRG, receives transmission
information TI from the corresponding node CN. The
transmission information TI will contain a source address
SAC and a target address, for example TAN. Therefore, in
step S51 the transmission/ reception unit TRG of the
gateway GW must first determine the appropriate
destination information to determine the node to which the
transmission information TI is to be sent. In step S52
(corresponding to step S5c2 in Fig. 5c) the
transmission/reception unit TRG of the gateway GW sends
the transmission information TI to the second terminal

node MN. In step S53 the second terminal node MN receives
the transmission information and in step S55 the second
terminal node MN sends an acknowledgement information
ACTAN to the gateway GW. In step S56 the acknowledgement
information is received. Whilst the transmission
information is sent in step S52 to the second terminal
node MN, the transmission information characteristics
determining unit TCM determines the transmission
characteristics TCH for the transmission of the
transmission information to the second terminal node MN.
As explained with reference to Fig. 4a, such transmission
characteristics may comprise preferably one or more
selected from the group consisting of the data amount DAM,
a transmission speed or a transmission rate TRT, a
transmission route, MR, AR along which the transmission
information has been transmitted to the second terminal
node, and a delay time of the packet transmission. The
delay time may be the actual delay time which the
transmission information needed to be transmitted from the
gateway GW to the second terminal MN. In accordance with
another example, the delay time may be the predetermined
delay for the transmission of the transmission
information; for example, a predetermined quality of
service (QoS) may be determined by the gateway GW and the
transmission information will only be transmitted to the
second terminal node MN with the prescribed quality of
service (QoS), i.e. with a predetermined delay time.

If the transmission characteristics have been determined
in step S54, for example as those shown in Fig. 4b, the
accounting unit ACC' determines the charging information
CH in step S57, on the basis of the transmission
characteristics, after the acknowledgement was received in
step S56. That is, only if actually an acknowledgement
information, for example ACTAN or ACTR4, is received in
step S56, the accounting unit ACC' will perform the

determination of the charging information CH on the basis
of the transmission characteristics TCH. Whilst in Fig. 5b
it is shown that the determination of the charging
information CH in step S57 is performed after receiving
the acknowledgement information in step S56, it may also
be provided that first several transmission information
such as TI, Ti', TI'' are respectively transmitted,
whereafter all acknowledgement information are collected
and finally the charging information is being determined.
Important in Fig. 5b is that the charging information CH
will only be determined (and the user of the second end
terminal node MN will only be charged) if an
acknowledgement information is received for the respective
transmission information. If there are more transmission
information to be sent from the gateway GW to the second
terminal node MN in step S58 in Fig. 5b, then the flow
chart will be re-entered at step S51. If there is no more
transmission information in step S58 the procedure is
ended.

Whilst in Fig. 4b it is shown that the transmission
information memory TIS' is adapted to store one or more
selected from the group consisting of a source address
SAC, the destination address TA of said transmission
information TI, TI', TI'', said determined transmission
characteristics TCH, said determined charging information
CH and said acknowledgement information ACTAN, it should
be understood that the transmission information memory
TIS' in Fig. 4b is only one example of such a memory used
for determining the charging information CH. Other
examples for the transmission information memory TIS' may
be devised by a skilled person. For example, it may be
devised that the acknowledgement information ACK in Fig.
4b is actually not stored but is only used as a trigger
for initiating the calculation of the charging information
CH. Therefore, it should be understood that the

calculation of charging information CH and the usage of
specific transmission characteristics TCH as shown in Fig.
4b is only one example. Important is, that the user of the
second end terminal MN will only be charged with charging
information CH, determined on the basis of any kind of
parameters reflecting the transmission of the transmission
information, if an appropriate acknowledgement information
is present for the transmitted transmission information.
However, other types of calculating charging information
or assessing transmission characteristics may be used.

For example, if the ad hoc network AHN is a packet
switched network AHN the transmission information TI, TI',
TI'' comprises one or more transmission packets IP1-IP5
and said acknowledgement information ACTAN, ACTAN',
ACTAN'' comprises one or more acknowledgement packets
ACK1-ACK5 (see for example Fig. 7), the transmission
information memory TIS' may be constituted as shown in
Fig. 4c. As shown in Fig. 4c, the transmission
characteristics determining unit TIM determines
transmission characteristics DAM, TRT for each
acknowledged (by ACK1-ACK5) transmission packet IP1-IP5.
Since all five packets IP1-IP5 were acknowledged a
complete charging information CH = 2 cent is determined by
the accounting unit ACC' for this transmission of the five
packets IP1-IP5. However, it may also be devised, in
accordance with another embodiment of the invention, that
a charging information CH is calculated individually for
each packet.

Although in Fig. 4c preferably, in accordance with another
embodiment, a so-called sequence number SN (as explained
below) may be used, it should be understood that the
accounting for individual transmission packets may also be
performed without the usage of such a sequence number. For
example, if the first packet (as transmission information)

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is sent out in step S5c2 in Fig. 5c, the gateway GW might
simply wait for the receipt of an acknowledgement
information ACTAN confirming the receipt of a transmission
packet. Thus, the gateway GW knows that the sent out
packet IP1 has safely arrived at the second terminal node
MN. Only after receiving the acknowledgement packet ACTAN,
the gateway will then send out the next packet IP2 and
will once more wait for the receipt of an acknowledgement
packet ACTAN'. If the gateway GW always waits for the
receipt of an acknowledgement for the last sent
transmission packet, there is no need to insert into the
respective transmission packet and the acknowledgement
packet respective information characterizing the
transmission packet and indicating in the acknowledgement
packet the specific transmission packet for which an
acknowledgement is done.

However, the usage of the sequence number SM indicating
the transmission order of the respective transmission
packet IP1-IP5 in a sequence of transmission packets IP1-
IP5 may preferably be used as a marker or a packet-
specific identifier such that acknowledgements may be
returned to the gateway GW on an individualized basis,
i.e. on a packet- specific basis. This is hereinafter
further explained with reference to the advantageous
embodiments in Figs. 7-15.

SEQUENCE NUMBER INSERTION

As already partially indicated above, the gateway GW shown
in Fig. 6 comprises a sequence number insertion unit SNI
adapted to insert into each transmission packet IP1-IP5 a
sequence number SN, such as 1, 2, 3, 4, 5, indicating the
transmission order of the respective transmission packet
IP1-IP5 in a sequence of transmission packets. Similarly,
in the terminal node, a sequence number determining unit

SND adapted to determine in each received packet a
sequence number indicating the transmission order of the
respective transmission packet in a sequence of
transmission packets is provided, wherein the .
acknowledgement information transmission unit ACKSN of the
second terminal node MN is adapted to transmit to said
gateway GW acknowledgement packets ACK1-ACK5 respectively
containing the detected sequence number of the received
packet whose receipt is to be acknowledged with said
respective acknowledgement packet ACK1-ACK5. Thus, the
sequence number SN serves the purpose as a general packet
identifier such that the transmitted transmission packet
may be identified on the second terminal side and such
that the acknowledgement packet not only generally
acknowledges the receipt of a transmission packet but the
receipt of a specific acknowledgement packet. This
sequence number or, more generally, a packet identifier is
denoted with SNx in the example in Fig. 4c. Thus, as shown
in Fig. 7, each transmission packet IP1, IP2, IP3, IP4,
IP5 ... IPx having a packet identifier 1, 2, 3, 4, 5 ... x
is acknowledged by a respective acknowledgement packet
ACK1, ACK2, ACK3, ACK4, ACK5 ... ACKx with packet
identifiers 1, 2, 3, 4, 5 ... x. The sequence number or
packet identifier could be stored in a IPv4 option field
or in a Ipv6 destination option header.

Thus, the relationship between packets and acknowledgement
packets can be provided by packet identifiers, for example
a sequence number. Although Figs. 7-15 shows the usage of
a "number" as a packet identifier, it should be noted that
also other identifiers may be used for providing the
packet-specific acknowledgements. Thus, the gateway has
detailed information about all packets which have received
the mobile node and can therefore perform a more accurate
flow control, for example also a more accurate accounting,
as shown in Fig. 4c.

Fig. 7 shows a flow chart of steps using the insertion of
sequence numbers (packet identifiers) in an
acknowledgement procedure, in accordance with one
embodiment of the invention. In step S71 a packet
identifier or a sequence number 1 is inserted in the first
transmission packet IP1. In step S72 the transmission
packet IP1 is transmitted to the second terminal node MN.
In step S73 the sequence number determining unit SND of
the second terminal node MN determines the packet
identifier or sequence number 1 in the received
transmission packet IP1. For example, the sequence number
1 indicates the position 1 of the transmission packet IP1
in a sequence of transmission packets IP1-IP5. In step S74
the acknowledgement packet including the detected sequence
number or packet identifier is transmitted to the gateway
GW. In step S75 the acknowledgement information detection
unit ACKM determines on the basis of the specific
acknowledgement packet ACK1 having a packet identifier 1
that the transmission packet IP1 with the packet
identifier (sequence number) 1 was indeed received by the
second terminal node.

Since each transmission packet with a specific packet
identifier is acknowledged with a respective
acknowledgement packet carrying the packet identifier
identifying the transmitted transmission packet, a clear
relationship between packets and acknowledgements can be
provided. That is, even if the roundtrip time RTT (see
Fig. 5c; the roundtrip time RTT is the minimum time the
gateway GW has to wait between transmitting a transmission
packet and receiving an acknowledgement packet thereof) is
not constant for each transmission packet IP, IP2, IP3 —
hence causing a possible receipt of the acknowledgement
packet ACK3 earlier than the receipt of the
acknowledgement packet ACK1 — there is still a clear

relationship between the sent packet and the returned
acknowledgement information.

For example, independently as to which acknowledgement
information ACK1-ACK5 arrives first, the accounting unit
ACC' can determine an individualized charging information
CH individually for each specific transmission packet IP1-
IP5. For example, as shown in the embodiment in Fig. 4c,
each packet IP1-IP5 which has been sent by the gateway GW
is now acknowledged by a specific acknowledgement packet
ACK1-ACK5. In this case, charging information CH can be
determined by the accounting unit ACC' individually for
each packet.

If there was no individualized relationship between the
sent transmission packet and the returned acknowledgement
packet, it may happen that the second terminal node MN
just acknowledges "the receipt of a packet" and not of a
"specific packet" and may in this manner claim that it is
only to be charged for a transmission packet which has
lower charging information CH than another packet. This is
avoided by the usage of the packet identifiers (sequence
numbers).

As explained above, in a first embodiment of the method in
accordance with the invention, as shown in Fig. 7, the
gateway only sends new packets to the mobile node (second
terminal node) MN if it has received an acknowledgement
for a proceeding packet. However, for example depending on
the roundtrip time RTT, this entails that the next packet
(e.g. IP2 after IP1) can only be sent after a certain
minimum roundtrip time RTT. For example, the roundtrip
time RTT may be in the order of 1 second and therefore a
new packet will only be sent after the expiration of a
time period of 1 second.

Thus, the gateway assigns each IP packet a sequence number before sending it to the mobile node MN. If sequence numbers are used as packet identifiers the sequence numbers may be ascending. As shown in Fig. 7, the mobile node MN acknowledges each packet with an acknowledgement with the same sequence number (packet identifier). As explained above in accordance with a first embodiment, the gateway GW only sends a new packet if it has indeed received the acknowledgement for the proceeding packet. However, due to the quite considerable roundtrip time RTT, the gateway GW uses a technique which is herein called the "window principle".

WINDOW PRINCIPLE

A particularly advantageous embodiment of the present invention for sending packets and receiving acknowledgements is if the gateway GW uses the sliding window principle, as illustrated in Fig. 7. Instead of sending one packet and waiting for an acknowledgement before sending the next packet the gateway GW sends out several packets wherein the number of sent out packets is specified by a predetermined transmission window WT. This transmission window WT is set by a transmission window unit WIN inside the gateway GW, as shown in Fig. 6. The predetermined transmission window WT indicates to the transmission/reception unit TRG to successively transmit to said second terminal node a number of transmission packets.

The transmission window WT is one of the group consisting of a transmission time window indicating a predetermined transmission time period (for example, if there is a fixed transmission rate a time period will indirectly indicate the number of packets to be sent out within the transmission window), a transmission window number of

successive transmission packets (directly indicating the
number of transmission packets), and a transmission data
amount indicating a predetermined amount of data to be
transmitted in one or more of said successive transmission
packets (if for example a fixed payload is possible per
transmission packet, the transmission window data amount
will indicate indirectly the number of packets to be
transmitted within the transmission window). However,
independently on what kind of transmission window is used,
the transmission window indirectly or directly indicates
the number of transmission packets to be sent to the
second terminal node MN without waiting for an
acknowledgement. That is, instead of sending out one
packet and waiting for an acknowledgement before sending
the next packet, the gateway GW sends out several packets.
If the transmission packets include the sequence number
(which may be preferably a sequence of ascending numbers),
the transmission window can also directly indicate the
sequence numbers of the transmission packets to be sent
out successively before waiting for an acknowledgement. In
the example in Fig. 7, the transmission window specifies
successive three sequence numbers of transmission packets
which should be sent out.

As shown in Fig. 7, there exists a first window WT which
comprises the transmission of 3 packets IP1, IP2, IP3.
Likewise, Fig. 7 also shows an updated or new window WT'
with packets IP2, IP3, IP4, window WT'' with packets IP3,
IP4, IP5 and window WT''' with packets IP4, IP5, IP6.
Thus, each window comprises a number of transmission
packets which are sent out successively without waiting
for an acknowledgment packet for a previous packet.
As shown in Fig. 7, the next window WT' is the one-packet-
slided version of the previous window WT, the window WT''
is the one-packet-slided version of the previous window
WT', and the window WT''' is the one-packet-slided version

of the previous window WT''. These new windows are arrived
at whenever an acknowledgment packet is received. That is,
after sending out the first, second and third packet IP1,
IP2, IP3 within the first window WT, the first
acknowledgement packet ACK1 is received at the gateway GW.
The receipt of this acknowledgement packet ACK1 for the
first packet IP1 triggers the sliding of the imaginary
transmission window WT to the window WT' now comprising
the packets IP2, IP3 and IP4.

Every new receipt of an acknowledgment packet such as ACK2
or ACK3 will respectively slide the window further one
packet, namely from WT' to WT'' after receiving ACK2 and
from WT' to WT'' after receiving ACK3. Thus, the window
WT''' is arrived at after having received the three
acknowledgment packets ACK1, ACK2, ACK3. In this case, the
packet ACK3 is the acknowledgment that not only the first
transmission packet IP1 was received but also the second
and third transmission packets IP2, IP3 (provided that the
round trip time RTT remains constant). Furthermore, the
packet ACK2 is the acknowledgment that not only the first
transmission packet IP1 was received but also the second
transmission packet IP2 and the packet ACK1 is the
acknowledgment that only the first transmission packet IP1
was received.

The same is true if an overtaking of transmission packets
and acknowledgement packets occurs or even if a packet
loss occurs. Actually, after transmitting the three
packets IP1, IP2, IP3 in the window WT, the
acknowledgement packet ACK1 should be received if the
round trip time remains constant and the window would be
slid one packet to the window WT'. However, if instead
only the acknowledgment packet ACK3 is received,
acknowledging also the receipt of IP2, IP3, then the
window WT is immediately slid to the window WT'''. Thus,

one can also say that the first, second and third
acknowledgement packet ACK1, ACK2, ACK3 respectively
acknowledging the receipt of the first, second and third
transmission packet IP1, IP2, IP3 of the present window WT
will respectively slide the window WT one, two or three
packets to the window WT', WT'' and WT''. In this manner,
the window WT is slid SN packets where SN is the sequence
number SN contained in the respective acknowledgment
packet acknowledging the receipt of the SN-th packet (and
other packets with lower SN) at the second terminal node
MN.

Thus, in the example of Fig. 7 the first step S7111 sets
the predetermined transmission window WT to successively
transmit three transmission packets IP1-IP3 to said second
terminal node MN. In steps S72, S721, S722 these packets
are successively sent to the terminal node MN. In steps
S73, S731, S732 a receipt of the respective transmission
packets IP1, IP2, IP3 is detected at the node MN and in
response to this acknowledgement packets ACK1, ACK2, ACK3
are respectively sent in steps S74, S741, S742 to the
gateway GW. In steps S61, S62, S63 the acknowledgement
information detection unit ACKM respectively detects the
receipt of the acknowledgement packets ACK1, ACK2, ACK3.
As can be seen in Fig. 7, the transmission/reception unit
TRG in step S75 sends out the next packet (i.e. the packet
with the next higher sequence number 4) after the receipt
of an acknowledgement package ACK1 is detected by the
acknowledgement information detection unit ACKM.
Furthermore, in step S75 the new transmission of the new
transmission packet IP4 is performed with reference to a
new transmission window WT'. Thereafter, if in step S62
the acknowledgement information detection unit ACKM
detects the receipt of a further acknowledgement
information packet ACK2, the window WT' is slid to the
window WT'' and the next transmission packet IP5 (with the

next higher sequence number 5) is transmitted in step
S751. When the next acknowledgement packet ACK3 is
received, the window WT'' is slid one packet to the window
WT''' and the next transmission packet IP6 is transmitted
in step S752. Thus, the transmission/reception unit TRG
always successively transmits the packets within the
current transmission window WT, WT', WT'', WT'''; if for
example packets IP1, IP2 and IP3 were already transmitted
in the first window WT and this window WT is slid to the
window WT', of course packets IP2, IP3 of this new window
WT' have already been transmitted such that the packet to
be transmitted next in the window WT' is the remaining not
as yet transmitted packet IP4. If on the other hand only
ACK3 is received the window WT is lid to WT''' and none of
the packets IP4, IP5, IP6 have as yet been transmitted.
Thus, in this case all the new packets IP4, IP5, IP6 of
the updated new window WT''' will be sent. Thus, whenever
the window WT, WT', WT'' is updated to a new window WT',
WT'', WT''', the transmission/reception unit TRG will
successively transmit those packets of the new window
which have not been transmitted in the old window.

Since in Fig. 7 the roundtrip time RTT is assumed to be
the same for each transmission/reception of
transmission/acknowledgement packets, it is clear that the
first acknowledgement to arrive will the acknowledgement
packet ACK1. However, if the roundtrip time RTT changes
after the transmission of the first transmission packet
IP1 in step S71, it might well be that the second
acknowledgement packet ACK2 is the first one to arrive. As
explained above, if ACK2 is the first acknowledgment
packet to arrive, the transmission/reception unit TRG of
the gateway GW slides the original window WT SN=2 packets
to the new transmission window WT'' comprising packets
IP3, IP4, IP5 of which IP4 and IP5 have as yet not been
transmitted, i.e. the transmission/reception unit TRG of

the gateway GW starts transmitting the transmission
packets IP4, IP5 of the window WT''. Therefore, whenever
it receives one of the three acknowledgement packets ACK1,
ACK2, ACK3 after the transmission of transmission packets
IP1, IP2, IP3 inside the first transmission window WT it
transmits the remaining not as yet transmitted packets of
the new window WT', WT'', WT''' respectively set on the
basis of SN in the respectively received acknowledgment
packet ACK1 (SN=1, i.e. slide window 1 packet), ACK2
(SN=2, i.e. slide window 2 packets) and ACK3_(SN=3, i.e.
slide window 3 packets).

As also already briefly mentioned above, whilst normally
(if the roundtrip time RTT remains constant in the
transmission window) the acknowledgement packet ACK1 will
be the first one to arrive at the gateway GW thus sliding
the window WT to the window WT', it might occur that the
sending out of new not as yet transmitted packets in a new
transmission window WT'' or WT''' is triggered by an
acknowledgement packet ACK2, ACK3 having sequence numbers
larger than the first transmitted transmission packet IP1.
In this case, the receipt of e.g. the acknowledgement
packet ACK3 already triggers the sending out of new
packets IP4, IP5, IP6 in the window WT''' whilst there is
no guarantee that IP2 and IP1 have actually arrived at the
second terminal node MN (since no acknowledgement
information ACK2, ACK3 has been received as yet). The lack
of receipt of ACK2, ACK1 can be due to a longer roundtrip
time RTT or can be due to having lost a transmission
packet and/or an acknowledgement packet. The two later
cases will be treated hereinafter in Fig. 8, 9.

It should be noted that in Fig. 7 there are three
possibilities how a new packet, for example IP4, will be
sent out after IP1, IP2, IP3 have been sent out. A first
possibility is that after receiving the first

acknowledgement packet ACK1 in step S61 the window WT is
lid to WT' and this causes the transmission of IP4 (the
remaining not transmitted packet in the new window WT').
Thus, independently of the receipt of the other
acknowledgement messages ACK2, ACK3 the receipt of the
first acknowledgement packet ACK1 already triggers the
sending out of a further predetermined packet IP4 within
the new transmission window WT'.

Another possibility is that after only receiving ACK2 the
window WT is slid to the window WT'' and thus the next
packet IP4 belonging to the next transmission window WT''
will be sent immediately and thereafter the succeeding
packet IP5 which is also in the new window WT'' and has as
yet not been transmitted.

A third possibility is that IP4 will be sent as the first
packet in the window WT''' which is set when only ACK3 is
received. After IP4 also packets IP5, IP6 in the window
WT''' will be sent because these have not been sent in
previous windows.

Thus, in one embodiment the successive receipt of the
three acknowledgement packets ACK1, ACK2, ACK3
successively triggers the sliding of the window WT to the
window positions WT', WT'', WT''' (one packet sliding of
the window) and the sending of not as yet transmitted
transmission packets successively in the respective new
transmission window WT', WT'', WT'''. In another
embodiment, in response to the receipt of only a
respective acknowledgement packet ACK2 before ACK1 or ACK3
before ACK1, ACK2 , the window WT is slid SN positions (SN
packet sliding) and comprises respectively 2 or 3 new
packets which have not been transmitted in the previous
window WT.

The sliding window principle avoids that the performance
of the communication system SYS is decreased due to a
waiting process for acknowledgements. Of course, the
optimum window size depends on the maximum throughput of
the connection between GW and MN and the roundtrip time
RTT, as explained before. The roundtrip time RTT is the
time which the gateway GW has to wait between sending a
packet and receiving the respective acknowledgement
packet. For example, if the transmission window WT is a
transmission window data amount, the transmission window
data amount is the product between the transmission speed
TRT on the transmission route MR, AR between the gateway
GW and the second terminal MN and the roundtrip time RTT.
For example, if the throughput is 1Mbit/s (i.e. the
transmission speed is 1Mbit/s) and the roundtrip time RTT
is 1 second, then the transmission window data amount is
1Mbit.

As can be seen in Fig. 7, the acknowledgement packet ACK1,
ACK2, ACK3 are accumulative, i.e. an acknowledgement with
a certain sequence number additionally acknowledges all
preceding packets. If for example the acknowledgement
packet ACK3 "overtakes" the acknowledgement packet ACK1,
then the acknowledgement packet ACK3 having a sequence
number of 3 additionally acknowledges that the second
terminal node MN has received also transmission packets
IP1, IP2. Thus, whenever an acknowledgment packet is
received, the gateway GW sends out one or more new
packet(s) depending on which acknowledgment packet arrived
at the gateway GW (sliding window technique).

LOST PACKETS

Fig. 8 shows the scenario of a lost acknowledgement
packet, namely the transmission/reception unit TRN does
send the acknowledgement packet ACK2 but the packet does

not arrive at the gateway GW due to a packet loss on the
transmission route. In the scenario of Fig. 8 the mobile
node MN will not be charged for the lost packet because no
acknowledgement information ACK2 is received (unless an
acknowledgment packet with a higher sequence number than 2
arrives; for example, an acknowledgment packet ACK3 will
acknowledge all previous packets in the sliding window
technique and therefore it will acknowledge also packet
IP2 thus causing a charging also for this packet).

Likewise, in Fig. 9 the transmission packet IP2 was indeed
sent by the transmission/reception unit TRG of the gateway
GW, however, it got lost on the transmission route to the
second terminal node MN.

In the case of Fig. 8 and Fig. 9 a lost packet detector
LPD in the gateway GW is adapted to detect that an
acknowledgement packet ACK2 or a transmission packet IP2
has gone lost during its transmission if after
transmission of a predetermined number of transmission
packets IP1-IP3 in a transmission window WT set by the
transmission window unit WIN, the sequence numbers in
successive acknowledgement packets ACK1, ACK3 do not match
with those set in the successive transmission packets IP1-
IP3. For example, in Fig. 8 the acknowledgement packets
ACK1, ACK3 are detected by the acknowledgement information
detection unit ACKM causing the transmission of further
transmission packets IP4, IP5 in step S83; S84. However,
the sequence numbers in successive acknowledgement packets
do not match with those set in the successive transmission
packets. That is, the sequence of sequence numbers 1, 2, 3
of the transmission packets IP1, IP2, IP3 do not match
with the sequence of sequence numbers 1, 3 detected from
the successively received acknowledgement packets ACK1,
ACK3. Thus, the gateway GW can determine with this kind of
comparison (out-of-sequence detection) that either the

acknowledgement packet ACK2 was not sent or that indeed
the transmission packet IP2 has not even reached the
second terminal node MN.

Likewise, in steps S91, S92 in Fig. 9 the lost packet
detector LPD will determine an out-of-sequence of sequence
numbers 1, 2, 3 of the transmission packets IP1, IP2, IP3
and the sequence numbers 1, 3 from the received
acknowledgement packets ACK1, ACK3. Despite the sending of
new packets IP4, IP5 in steps S93, S94, the lost packet
detector LPD determines that either the transmission
packet IP2 has not arrived at the second terminal node MN
or that the acknowledgement packet ACK2 was not sent.

In both scenarios in Fig. 8 (lost acknowledgement packet)
and in Fig. 9 (lost transmission packet), the mobile node
MN is not charged for the lost transmission
packet/acknowledgement packet because no acknowledgement
is received at the transmitting gateway GW (unless an
acknowledgment packet with a higher sequence number such
as ACK2, or ACK3 is received as explained above, because
higher sequence number acknowledgment packets also
acknowledge the receipt of the packets of lower sequence
number even if they have not been received). This is in
the general context of the invention that the user of the
second terminal node MN should only be charged for packets
which have been acknowledged with acknowledgement
information (acknowledgement packets).

However, the mobile node MN may be cheating, i.e. it might
have actually received the transmission packet IP2 and
might intentionally not send an acknowledgement packet
ACK2 because it tries to avoid being charged for it. This
can be avoided if in Fig. 8 and Fig. 9 the gateway GW
always charges the second terminal node MN if a
transmission packet IP2 has been sent out, independently

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whether an acknowledgement information is received. Of
course, the gateway GW still needs some information which
indicates that the packet has actually arrived because in
accordance with the invention only packets should be
charged which have reached the second terminal node.
However, it is possible that a lost packet detector LPD is
also provided on the terminal node side MN and this lost
packet detector LPD detects an incorrect sequence of
transmission packet sequence numbers, i.e. in Fig. 9 the
lost packet detector LPD on the mobile node side MN
detects 1, 3, ... which is a clearly out-of-sequence
detection because there is no sequence number 2. In such a
case, as will be explained with more details with
reference to Fig. 15, a request for retransmission can be
made by the second terminal node MN for the out-of-
sequence number 2 and in this case, after receiving the
retransmission request, the gateway GW can use the
retransmission request as a kind of acknowledgement that
the second transmission packet IP2 was lost. In this case
the accounting unit ACC' will only charge for the
retransmitted packet rather than the original packet.
Therefore, still even in this scenario only packets are
charged for which some kind of
confirmation/acknowledgement was received from the second
terminal node MN.

On the other hand, in Fig. 8, the gateway GW, in
particular its accounting unit ACC', can do nothing else
but not charge for the transmission packet IP2 because
neither a retransmission request nor an acknowledgement
ACK2 is received. In this case, as explained with
reference to Fig. 11, an acknowledgement request can be
made from the gateway GW to the second terminal node MN to
recollect the missing acknowledgement. If it is finally
received, then the transmission packet IP2 will be
charged.

However, it should first be understood in accordance with
this embodiment that the gateway GW as well as the second
terminal node MN can comprise a lost packet detector LPD
which basically detects the lost acknowledgement and the
lost packet if the sequence numbers which successively
occur in a transmission window at the gateway GW and the
mobile node MN do not coincide with the expected sequence.

TIMER EMBODIMENTS

As was explained above with reference to Fig. 7, when
using the sliding window principle, the receipt of one or
more acknowledgment packets causes a sliding of the
original window WT to a new window WT', WT'', WT''',
either in successive single packet slides with each
successive receipt of an acknowledgment packet ACK1, ACK2,
ACK3, or in SN packet slides when only acknowledgment
packets ACK2 or ACK3 are received. Additionally, a single
acknowledgement for one of the packets transmitted within
the transmission window WT acknowledges the receipt of the
transmission of all transmission packets with lower order
SN than contained in the acknowledgment packet.

Fig. 10 shows a flow chart for the steps carried out by
the lost packet detector LPD comprising a timer T in
accordance with another embodiment of the invention.

Essentially, a timer T of the lost packet detector LPD is
adapted to count a predetermined time duration ΔT. The
timer T is started with each new transmission of a
transmission packet, as indicated with steps S101, S102,
S103, S107, S108. When counting the predetermined time
duration ΔT after a respective restart, the timer is being
stopped whenever an acknowledgement packet is received for
the last transmitted transmission packet within the

predetermined time duration ΔT, as seen with steps S104, S105, S106. Thus, the timer is used to control the reception of acknowledgement packets.

Preferably, the time duration ΔT of the timer T should be adapted to the roundtrip time RTT, i.e. slightly longer.

As shown in Fig. 10 and as explained above with reference to Fig. 7 (window principle), a single acknowledgement such as the one received in step S104 in Fig. 10 acknowledges the transmission of all packets within the transmission window WT.
As also explained above regarding the "sliding window principle", the receipt of the acknowledgment packet ACK1 in step S104 slides or shifts the window WT to the window WT' and it is this shifting of the window which causes the timer T to be restarted because the new window WT' comprises still one packet, namely IP4, which has as yet not been transmitted (see also Fig. 7). For the transmission of this new packet IP4 in the new window WT' the timer T is restarted in step 107. Likewise, the ACK2 shifts the window WT to the window WT'' thus causing a transmission of IP5 and a restart of the timer T in step S108. Only the acknowledgment packet ACK6 actually stops the timer T because the receipt of ACK3 causes the transmission of IP6, i.e. the last not sent packet in the new_transmission window WT'''. Thus, all packets in the present window WT''' will have been sent and acknowledged and there is no reason for a further timer monitoring of any receipt of acknowledgment packets any more.

However, as shown in Fig. 11, there may be a case where after having sent three transmission packets IP1, IP2, IP3 the timer T counts the predetermined time duration ΔT and times out. That is, after starting the timer T in step S113 the timer counts the predetermined time duration ΔT

within step S113' and, since all acknowledgement packets
ACK1, ACK2, ACK3 were lost, there is a time out of the
timer. One possibility in such a situation is that the
gateway GW just accepts that no acknowledgement has been
received whatsoever for any of the three transmission
packets IP1, IP2, IP3 and just stops the transmission
(transmission stop). A second possibility, as shown in
Fig. 11, is that after step S113' (after the timer T has
counted the predetermined time duration ΔT), in step S114
an acknowledgement request unit SOL which may be part of
the lost packet detector LPD, transmits to the second
terminal node MN an acknowledgement request packet
SOL_ACK3 including a predetermined sequence number 3 of a
transmission packet IP3 which was transmitted but for
which no acknowledgement information has as yet been
detected by said acknowledgement detection unit ACKM. The
acknowledgement request message SOL_ACK3 requests from the
second terminal node MN the transmission of an
acknowledgement packet ACK3 acknowledging the receipt of
the transmission packet having the predetermined sequence
number 3.

Whilst the acknowledgement request SOL may request the
transmission of an acknowledgement packet having an
specified sequence number, in accordance with one example
of this embodiment, the acknowledgement request unit SOL
is adapted to transmit to said second terminal node MN an
acknowledgement request packet SOL_ACK3 including the
sequence number 3 of the last transmission packet IP3
transmitted in the transmission window WT.

As shown in Fig. 11, the transmission of the
acknowledgement request packet SOL_ACK3 in step S114
causes the mobile node MN to transmit the acknowledgement
packet ACK3 in step S115 whereafter further transmissions
of packets IP4 and IP5 start with a respective starting of

the timer T in step S116, S117 whenever a new transmission
packet is transmitted.

However, as shown in Fig. 11, of course the
acknowledgement request package SOL_ACK3 transmission in
step S114 is a new packet transmission just as the
transmission of transmission packets IP1, IP2, IP3.
Therefore, if after the transmission of the transmission
packet IP3 and the starting of the timer ST in step S113,
the timer T times out in step S113', it is also preferable
that the timer T is started when the acknowledgement
request unit SOL starts transmitting the acknowledgement
request package SOL_ACK3.

Whilst in Fig. 11 the acknowledgement packet ACK3 stops
the timer and the timer is started again in step S116 for
the new transmission of packet IP4, Fig. 12 shows a case
where the timer is set in step S121' when sending the
acknowledgement request package SOL_ACK3 in step S121. If
in step S122 the timer T times out and no acknowledgement
information is detected by said acknowledgement
information detection unit ACKM within said time duration
after transmitting said acknowledgement request package
SOL_ACK3, the transmission/reception unit TRG stops the
transmission of further transmission packets after step
S122. The reasons for not receiving the requested
acknowledgement packet ACK3 in Fig. 12 thus causing the
time out of the timer T in step S21, can be manifold
reasons. One is that also the acknowledgement request
package SOL_ACK3 did not reach the second terminal node MN
because it got lost on the way, as shown in Fig. 12.
Another possibility is that the second terminal node MN
did either actually not send the acknowledgement packet
ACK3 or the acknowledgement packet ACK3 got lost on its
way to the gateway GW. The timer T takes care of all these
situations by performing a transmission stop if no

acknowledgement packet ACK3 is received within the
predetermined time duration ΔT.

As may be understood from Fig. 11 and Fig. 12, if all
acknowledgement packets get lost (or are not sent by the
second terminal node MN), the gateway GW does not send new
packets and hence does not restart the timer T. This
results in the time outs, as illustrated in Fig. 11 and
Fig. 12. In Fig. 11 the gateway GW solicits an
acknowledgement from the mobile node for the last sent
packet. The mobile node resends the acknowledgement in Fig.
11 and the remaining packets IP4, IP5 can be transmitted.
The same procedure can be applied if the transmission
packets get lost instead of the acknowledgements. In this
case the mobile node must nevertheless send the solicited
acknowledgement packet ACK for example for the packet 3
although it may not have actually received any packets
(because they got lost during the transmission from the
gateway GW to the mobile node MN). Thus, the mobile node MN
is charged for packets it has not received. Again, this
prevents misbehaviour of the mobile node MN. If the mobile
node MN decides not to send the acknowledgement package
ACK3 or if the acknowledgement request packet SOL_ACK3 does
not reach the second terminal node MN, this results in a
transmission stop as shown in Fig. 12. If in Fig. 12 the
timer expires, GW will stop the transmission as it assumes
that either the route to MN is interrupted or MN does not
want to receive any packets anymore.

Therefore, in accordance with another embodiment of the
invention, as shown in Fig. 13, the timer times out in step
S131' after counting the time duration ΔT after
transmitting the transmission packet IP3 in step S131. In
this respect step S131 and S131' in Fig. 13 are identical
to steps S113 and step S113' in Fig. 11. In step S132 a
route check unit RC detects whether a transmission route to

said second terminal node MN exists. If after the timer T
times out in step S131' the route check unit RC detects in
step S132 that a transmission route like MR or AR exists to
the second terminal node MN, the acknowledgement request
unit SOL will transmit to the second terminal node MN the
acknowledgement request packet SOL_ACK3. In Fig. 13, if the
route check unit in step S132 determines that a route
exists, steps S133', S133, S134, S135, S136 correspond to
the steps S114', S114, S115, S116 and S117, respectively of
Fig. 11.

If the route check in step S132 or S142 in Fig. 14 is
negative, i.e. the route check unit RC detects that no
transmission route is available to the second terminal node
MN, the transmission/reception unit TRG of the gateway GW
stops transmission in step S143. In Fig. 14 step S141,
S141' and step S142 correspond to the steps S131, S131',
S132.
It should be noted that in Fig. 13 and in Fig. 14 the route
check unit RC shown in Fig. 6 detects whether a
transmission route to the second terminal node MN exists by
accessing standard routing protocols.

It should also be noted that in Fig. 13 and Fig. 14 there
is a possible problem in that the second terminal node MN
has no incentive to acknowledge the last packets of a
session. Or even worse, it may systematically use repeated,
short sessions instead of long ones. However, it is assumed
that this misuse is not attractive to the user of the
second terminal node MN because the session set-up creates
some delay and overhead. Furthermore, a fixed fee for each
session set-up may be charged.

With reference to Fig. 9 it was already described above
that also the second terminal node MN may detect that a
transmission packet should have been transmitted and was

not received. This can for example be done by checking the
sequence of sequence numbers extracted from the received
packets. In such a case (as shown in Fig. 15), the second
terminal node MN may request a retransmission of a packet
of which it believes that it should have been received.
In the embodiment in Fig. 15 the first transmission window
WT comprises the sending of transmission packets IP1, IP2,
IP3 in steps S151, S152, S153. In step S154 the first
transmission packet IP1 is acknowledged by sending an
acknowledgement packet ACK1 from the second terminal node
MN to the gateway GW. The receipt of the acknowledgement
packet ACK1 triggers the sliding of the window WT to WT'
and thus the sending of the next transmission packet IP4 in
this next transmission window WT' (as explained above the
receipt of any acknowledge message for a transmission
packet contained in the transmission window WT causes the
sliding of the window WT to WT', WT'' or WT''' and thus the
sending of further not already transmitted packets in the
respective new transmission window WT', WT'', WT''').

After receiving the third transmission packet IP3 in step
S153, the lost packet detector LPD on the second terminal
side MN is in a position to detect that the transmission
packet IP2 should have been sent but was lost on its way
(indicated with the "x" in the message flow in step S152).
That is, since the second terminal node MN knows that in
the transmission window WT three packets IP1, IP2, IP3
should have been sent but it has received only packets with
sequence numbers 1, 3, it concludes that the second
transmission packet IP2 was lost. Therefore, in step S156 a
packet retransmission request unit ARQ in the second
terminal node transmits to the gateway GW the
retransmission request packet SEL_ACK3 (2). The
retransmission request SEL_ACK3 (2) includes the sequence
number 3 of the packet whose receipt should be acknowledged
as well as a sequence number 2 of a transmission packet

which is requested to be retransmitted from said gateway
GW. In step S157, in response to the retransmission request
packet SEL_ACK3 (2) in step S156, the transmission
/reception unit TRG of the gateway GW transmits the
requested packet IP2 again in step S157. However, when the
packet IP4 is transmitted in step S155 the second terminal
side MN still has not received the requested second
transmission packet IP2 and therefore, in step S158, the
packet retransmission request unit ARQ sends another
retransmission request packet SEL_ACK4 (2). This
retransmission request packet acknowledges the receipt of
the fourth transmission packet IP4 and simultaneously
requests the retransmission of the transmission packet with
the sequence number 2. The request packet SEL_ACK4 (2)
requests another retransmission of the second transmission
packet IP2 because at this point in time the second
transmission packet IP2 sent in step S157 in response to
the first retransmission request message SEL_ACK3 (2) has
not as yet arrived at the second terminal node MN. However,
since after step S157 the retransmission of the second
packet IP2 is successful, the transmission of the next
packet IP5 – before receiving the renewed retransmission
request in step S158 – is confirmed with an acknowledgement
packet ACK5. However, due to the time relationship in Fig.
15 the second packet IP2 will be sent again to the second
terminal node MN in step S159 in response to the additional
retransmission request SEL_ACK4 (2).

As may be seen from Fig. 15, if the lost packet detector
LPD on the second terminal side MN detects the loss of a
transmission packet such as IP2 (because it knows that the
complete sequence 1-2-3 should have been received if a
transmission window WT is used), then the packet
retransmission request unit ARQ sends repeated
retransmission requests SEL_ACK3 (2), SEL_ACK4 (2) with
each receipt of a new transmission packet IP3, IP4 until

after step S157 the requested transmission packet IP2
actually arrives at the second terminal node MN.

Since the last packet IP4 of the second transmission window
WT' could not be acknowledged – because the retransmission
request SEL_ACK4 (2) had to be sent because the second
transmission packet IP2 still had not arrived, the
acknowledgement packet ACK4 for the last transmission
packet IP4 of the second transmission window WT' is only
sent after step S157_in step S160. Therefore,
acknowledgement packets like ACK4 for other transmitted
packets are only sent after an earlier lost transmission
packet like IP2 is actually sent by the
transmission/reception unit TRG of the gateway GW. This is
possible because preferably the embodiment in Fig. 15
operates on a kind of "handshake" principle, i.e. the
second terminal node MN will only answer with any kind of
message after it has received a further transmission packet
from the gateway GW.
On the other hand, the separate transmission of ACK4 in
step 160 in Fig, 15 is optional because the retransmission
request SEL_ACK4 (2) not only contains the request for a
retransmission of packet IP2 but also an acknowledgment
ACK4 for the packet IP4.

If packets get lost the receiving node can notice this by
checking the sequence numbers of the received packets. The
receiving node MN is charged for all packets including lost
ones. However, the second terminal node MN may request the
retransmission of a lost packet. In this case the second
terminal node MN sends the selective acknowledgement
SEL_ACK3 (2), SEL_ACK4 (2) in which it indicates the
sequence number of the packet it has not received. The
gateway GW or respectively its accounting unit ACC' will
not charge packets which have been retransmitted. In the
example in Fig. 15 the second terminal node MN sends

selective acknowledgement packets SEL_ACKs for each
received packet which does not have the sequence number 2.
As explained, this leads to two retransmissions of the
packet IP2 in steps S157, S159. This can be avoided if the
second terminal node MN only sends selective
acknowledgement packets SEL_ACK in certain intervals, e.g.
corresponding to the roundtrip time RTT. That is, if the
retransmission unit ARQ in the second terminal node MN
would at least wait the roundtrip time RTT, as indicated
with RTT in Fig. 15, then it can be achieved that the
desired second transmission packet IP2 arrives and thus the
second terminal node MN has no need to again request the
retransmission of the packet IP2.

In Fig. 15 it is assumed that packets do not overtake each
other during the transmission within a transmission window
WT. That is, if no packets get lost, transmission packets
IP1, IP2, IP3 will also arrive in the order 1-2-3 at the
second terminal node MN. However, due to different delays
or possibly different transmission routes for individual
packets, it might occur that the receipt sequence is not 1-
2-3 but 1-3-2. If the lost packet detector LPD on the
second terminal side MN in such a case immediately sends a
selective acknowledgement retransmission for the packet
with the sequence number 2, it might do so too early
because actually the second transmission packet IP2 might
arrive, only just a little bit later. In this case the
second terminal node MN should wait with sending a
retransmission request SEL_ACK to see whether the assumed
"packet loss" actually was a disorder of packets. Since the
packet retransmission is performed "transmission window-
wise" it is wise if the retransmission unit ARQ waits at
least the roundtrip time RTT plus the sending out time
(i.e. size of packet/transmission rate; e.g. 1Mbit/1Mbit/s=
1 second) multiplied with the number of packets to be
transmitted within each transmission window WT. The reason

for this is that in the worst case the packets can arrive
in such a disordered manner as 3-1-2. In this case the
packet IP3 was the last sent packet but was actually the
first received packet. Since the actually first sent packet
was the transmission packet IP1 with the sequence number 1,
in the worst case the transmission packet IP1 might still
arrive as the last received packet at the second terminal
node MN, for example in a sequence order of 3-2-1. Thus, it
can be avoided that there is an unnecessary request for
retransmission from the second terminal node MN.

ACKNOWLEDGEMENT TUNNELING LINKS

Fig. 5a shows the communication system SYS in accordance
with the invention, including a first network IN with at
least a first terminal node CN, an ad hoc network AHN with
at least a second terminal node RN1-RN4, MN, and a gateway
GW for forwarding transmission information TI between said
first terminal node CN of said first network and said
second terminal node of said ad hoc network AHN. As shown
in Fig. 5a (and as also described above with reference to
Fig. 3a), inside the mobile ad hoc network AHN
communication connections such as wireless LAN and WAN
connections or Bluetooth Connections, are used in order to
route the transmission information from the gateway GW to
the second terminal MN and to route the acknowledgement
information from the second terminal node MN to the gateway
GW along a transmission route MR, AR. It should be
understood that the embodiments and examples of the
invention shown in Fig. 5a, 5b, 5c, and in Figs. 6-15, may
be carried out by using such wireless connections along the
main route MR and the alternative route AR. However, as
hereinafter explained with reference to Fig. 16a, 16b
particularly advantageous is if the gateway GW establishes
an IP tunnel to the receiving mobile node MN, i.e. IP
packets such as IP1-IP5 in Fig. 7, are encapsulated in IP

packets. In this case, the mobile node MN has to send an
acknowledgement to the gateway GW for each encapsulated
packet it receives. Nodes are charged and compensated for a
packet as soon as the respective acknowledgement has
reached the gateway GW.

Fig. 16a shows the communication system SYS in accordance
with the invention, in particular with respect to the usage
of global addresses SAC, GAG, GAN and local ad hoc
addresses ADAG, ADA1, ADA2, ADAN. It should be noted that
the tunnel TUN1 to be described hereinafter with reference
to Fig. 16b only performs a flow control, for example for
the accounting purpose, but not for congestion control.
Furthermore, the tunnel mechanism may retransmit packets
only on demand. However, as also shown in Fig. 17, on top
of the IP tunnel TUN1, any transport protocol such as TCP
(Transport Control Protocol) or UDP (User Datagram
Protocol) can be run. It should be noted that such a tunnel
may be required also due to other reasons, e.g. if
different addressing schemes are used. In this case, the
tunnel can be reused for accounting purposes as well. If a
micro-mobility protocol is employed that takes the
existence of a mobility anchor point, the IP tunnel can
alternatively be established between the mobility anchor
point and the mobile node. That is, it should be noted that
it is not only possible to set up the tunnel(s) between the
gateway GW and the second terminal node MN but also between
any other node of the operator-controlled network IN and
the second terminal node MN. Such another node may be the
aforementioned mobility anchor point or any other terminal,
switching point, base station, access point etc. Therefore,
it should be noted that the exchange of transmission and
acknowledgment packets and the accounting as described
above to exist between the gateway GW and the second
terminal node MN may likewise take place between any other
node of the network IN and the second terminal node MN.

Fig. 16a shows an example of addressing and routing in the Internet. Hosts are identified by complete IP addresses whereas sub-networks are identified by prefixes. Hosts always have the same prefix as their subnet. In the scenario of Fig. 16a the corresponding node CN is located in a subnet SUBNET1 with a prefix 1. Therefore, the source address or global source address SAC is 1.1. Likewise, the gateway GW belongs to the subnet SUBNET2 with prefix 2 and has the global address GAG 2.1. Hereinafter, a global address of a unit or host inside the subnets SUBNETS1, SUBNET2 should be understood as a fixed address belonging to a fixed location.

Despite the fact that an intrinsic property of the ad hoc network AHN is the feature that the respective nodes RN1-N4, MN are mobile nodes, the mobile nodes may also have assigned to it a global address, for example for the mobile node MN the global address GAN = 2.2. This global address GAN is known to the corresponding node CN as target address TAN but MN also contains an ad hoc address ADAN. Only the GW knows both addresses. Likewise, the target address TA4 of the node RN4 will have a global address as well as an ad hoc address.

In ad hoc networks, addressing and routing is flat and mobile devices can use arbitrary addresses, for example the ad hoc addresses ADAG = A for the gateway GW and ADA1 = B, ADA2 = C and ADAN = D for the mobile nodes RN1, RN2 and MN, respectively. Thus, the actual target address TAN of the second terminal node MN consists of a global address GAN = 2.2 known to the corresponding node CN and a local or ad hoc address ADAN = D only known to the gateway GW. If the mobile node MN connects to the Internet and wants to be reachable by external corresponding nodes CN, it must have this global address GAN as well because the corresponding

node CN, when sending the transmission information TI
cannot know which temporary ad hoc address the mobile node
MN has at any one time. For this reason the mobile node MN
has set global address GAN = 2.2. The mobile node MN uses·
the same prefix "2" as the subnet SUBNET2 to which it is
attached. Hence, the mobile node MN uses the global address
GAN = 2.2 additionally to its ad hoc address ADAN = D, as
shown in Fig. 16a. As also explained before, the gateway GW
essentially belongs to both networks SUBNET1, SUBNET2 and
it must therefore also have a global address GAG = 2.1 to
be reachable by the corresponding node CN as well as an ad
hoc address ADAG = A in order to route information to the
second terminal node MN and to receive information
therefrom. Thus, also the gateway GW maintains the two
types of addresses.

If the mobile node MN wants to communicate with the
Internet, packets must be tunnelled within the ad hoc
network, as illustrated in Fig. 16b.

As shown in Fig. 6, the transmission/reception unit TRG
comprises a first tunnel set-up unit IPTUN for setting up a
first tunnel link TUN1 between the gateway GW and said
second terminal node MN. The transmission/reception unit
TRG transmits the transmission information TI and receives
said acknowledgement information, e.g. ACTAN, ACTAN',
ACTAN'' in Fig. 5c, to and from the second terminal node MN
respectively through said first tunnel link.

The first tunnel link TUN1 acts as a kind of "rigid link"
which is directly set up between the gateway GW and the
second terminal node MN whose transmission/reception unit
TRG respectively comprises the aforementioned first tunnel
set-up unit IPTUN, as shown in Fig. 6. The main advantage
of using a tunnel connection between the mobile node MN and
the gateway is that there can be no disturbance of the

transmission information and acknowledgement information
transmission and a dedicated connection is provided solely
to perform the flow control, for example the accounting of
packets inside the ad hoc network. It should be noted that
in principle the tunnel TUN1 is used for flow control and
accounting but not for congestion control. It may also be
noted that the tunnel TUN1 between the mobile node MN and
the gateway GW might be required also due to other reasons,
e.g. if different addressing schemes are used. In this
case, the tunnel can be reused for accounting purposes as
well.

Preferably, and as also shown in Fig. 16b, the first tunnel
set-up unit IPTUN sets up said first tunnel link TUN1 by
encapsulating transmission packets IPx into modified
transmission packets IPxx generated and transmitted by said
transmission/reception unit TRG. That is, in accordance
with the invention IP packets (transmission packets and
acknowledgement packets) are encapsulated in IP packets on
the tunnel TUN1.

As shown in Fig. 16b the transmission information TI can be
an IP packet IPx having a payload data section DPx and an
addressing portion APx. The IP transmission packet IPx
comprises in the addressing portion APx the global source
and destination addresses S:1.1 and D:2.2 indicating
globally the origin and the destination for the
transmission packet IPx. Thus, the corresponding node CN
sends out an IP transmission packet with a global
destination address 2.2. This packet is routed to the
gateway GW where an address encapsulation must take place
into a new packet IPxx consisting of the IP packet IPx
(with data portion DPx and addressing portion APx) however
with a new addressing portion APxx used for the routing and
tunnelling of the IP packet IPx in the ad hoc network AHN.

In the addressing portion APxx of the IP packet IPxx an
encapsulation of the addresses takes place. Thus, the first
tunnel set-up unit IPTUN is adapted to respectively
encapsulate a transmission packet IPx received from said
first terminal node CN and having a global source address
S:1.1 of said first terminal node CN and a global
destination address D:2.2 of the second terminal node MN
into a modified transmission packet IPxx which has in its
addressing portion an ad hoc source address S:A of said
gateway GW and an ad hoc destination address D:D of said
second terminal node MN. That is, the IP packet IPx is
fully encapsulated in a modified IP packet IPxx with a new
header APxx which is used for the routing in the ad hoc
network. Thus, the modified transmission packet IPxx is
routed from the local ad hoc address A to the local
destination address D.

Thus, when the first packet IPx having a destination
address of the gateway D:2.2 arrives at the gateway GW, the
gateway GW is considered the new source for forwarding
transmission information inside the ad hoc network AHN.
Therefore, the earlier global destination address D:2.2 is
changed into the new source address S:A in the ad hoc
network. The global destination address D:2.2 of the second
terminal node MN is changed into the local ad hoc network
address D:D. Thus, within the ad hoc network AHN the
modified transmission packet IPxx is routed from the source
GW (S:A) to the destination MN (D:D) using the local ad hoc
addresses only. Thus, the gateway GW encapsulates the
transmission packet IPx into another IP packet IPxx with a
destination address A and tunnels it to the mobile node MN.
Of course, on the mobile node side MN the packet IPxx is
de-capsulated in order to retrieve the information about
where the packet originally came from (source address
S:1.1) and to retrieve the payload data from the data
portion DPx.

Since a "virtual" or "logical" tunnel TUN1 is set-up
between the gateway GW and the second terminal node MN, the
exchange of the transmission packets and acknowledgement
packets between the two nodes GW, MN is carried out
completely undisturbed from any other transmission of
packets inside the ad hoc network. Thus, the tunnel TUN1
acts as a kind of rigid connection only specially dedicated
to the exchange of transmission and acknowledgement
packets, which is for example useful for the accurate
accounting, as explained above. The usage of the first
tunnel is also advantageous in cases where the
corresponding node and the ad hoc terminals do not have the
same format of addresses. Another advantage of the tunnel
set-up is that the packet from the corresponding node
remains intact, i.e. its format is not changed in the
gateway when it is transmitted through the tunnel to the
second terminal node.

Fig. 17 shows another embodiment of the invention where a
specific reliable tunnelling protocol can be used on top of
the first tunnelling protocol TUN1. One possibility is to
set up a TCP tunnel additionally to the IP tunnel TUN1
between the gateway GW and the mobile node MN. The TCP
protocol can be a light version that does not perform
retransmits and that does not use an congestion control
algorithms. This approach is illustrated in Fig. 17 where a
second tunnel TUN2 is encapsulated in the first tunnel
TUN1.

As indicated in Fig. 6, to set up the second tunnel TUN2,
the gateway GW and the mobile node MN respectively comprise
a second tunnel set-up unit TCPTUN for setting up the
second tunnel link TUN2 encapsulated within said first
tunnel link TUN1 between said gateway GW and the second
terminal node MN. The transmission/reception unit TRG

transmits the transmission information TI and receives
acknowledgement information, such as ACTAN, ACTAN', ACTAN''
in Fig. 5c, to and from the second terminal node MN
respectively, by using said second tunnel link TUN2
encapsulated within said first tunnel link TUN1, as
schematically indicated in Fig. 17 where the second tunnel
is surrounded or encapsulated by the first tunnel link
TUN1. "Using" the second tunnel link TUN2, in this context,
means that the protocol of said second tunnel link TUN2 is
used.

As shown in Fig. 17, the second tunnel set-up unit TCPTUN
sets up the second tunnel link TUN2 by encapsulating the
transmission packets IPx having the data portion DPx and
the addressing portion APx similar as in Fig. 16b and being
received from the first terminal node CN into modified
transmission packets IPx' including the packet IPx having
the data portion DPx and the addressing portion APx and a
new header or addressing portion APx' which for the example
in Fig. 17 is assumed to be a TCP header with a TCP source
and destination address. Thus, the received IP packets APx
are embedded in a second tunnelling protocol such as TCP.

The encapsulated or modified TCP transmission packets IPx'
including the IP packet IPx with the data portion DPx and
the addressing portion APx and the new header APx' are then
encapsulated by the first tunnel set-up unit IPTUN into
modified transmission packets IPxx' including the TCP
packet IPx' and an addressing portion APxx' similar to APxx
in the modified transmission packet IPxx in Fig. 16b. Thus,
the TCP packet IPx' (including the encapsulated IP packet
IPx) is once more encapsulated into a modified transmission
packet IPxx' by the first tunnel set-up unit, similarly as
in Fig. 16b, only that the packets which are encapsulated
by the first tunnel set-up unit IPTUN are the TCP packets

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IPx' which have already been encapsulated using the second
tunnelling protocol.

As explained above, the first tunnel TUN1 might already be
set up for other reasons, e.g. if different addressing
schemes are used. In this case, the already set-up tunnel
can also be used for the exchange of transmission
information and acknowledgement information and for the
accounting as described above.

Preferably, the first tunnel set-up unit IPTUN sets up as
said first tunnel link TUN1 an IP (Internet protocol)
protocol. Preferably, the second tunnel set-up unit TCPTUN
sets up as second tunnel TUN2 a TCP (Transport Control
Protocol) protocol, or a stack of a L2TP (Layer-2-
Tunnelling protocol) protocol, a PPP (Point-to-Point
Protocol) protocol and a UDP (User Datagram Protocol)
protocol. The second tunnel may typically be set up by
using any protocol which normally does not allow the
exchange of acknowledgment information and transmission
information whilst the first tunnel may be set up using any
IP protocol version.

With the usage of the tunnel (either one tunnel or two
tunnels) an enhanced flow control of packets is possible in
order to ensure that nodes properly acknowledge packets.

Finally, Fig. 18 shows another embodiment of the invention
in which the first tunnel TUN1 is formed by an IP tunnel
between the gateway GW and the mobile node MN and the
second tunnel TUN2 is formed by a stack of a UDP (User
Datagramm Protocol) protocol, a L2TP (Layer-2-Tunnelling
protocol) protocol and a PPP (Point-to-Point) protocol. The
PPP protocol is set up over the L2TP and the UDP protocol.

INDUSTRIAL APPLICABILITY

As described above, in accordance with the invention it is possible to perform a more accurate flow control of packets in an ad hoc network AHN because each transmission packet is acknowledged with an acknowledgement packet. This can be used advantageously not only for a general more accurate flow control but also for a more accurate accounting. That is, in accordance with the invention a packet transmission monitoring for an accurate accounting in ad hoc networks is achieved preferably by establishing an IP tunnel between the gateway (or a mobility anchor point or in fact any other node in the operator-controlled network IN) and the receiving node which is used for accounting and by performing an enhanced flow control of the packets sent through this IP tunnel in order to ensure that nodes properly acknowledge packets.

Although above the specific example of using a gateway GW is described it should be noted that any other node in the operator-controlled network IN could be used for carrying out the flow control and accounting functions of this invention. This other node may, however, be connected to the gateway through some connection in order to initiate the transfer of received transmission information TI from the gateway GW to the second terminal node MN).

Above also specific examples of window sizes of 3 packets were described, however, the invention is of course not restricted to this window size. Any other window size may be used depending on the specific application.

Furthermore, specific protocols were described as examples for the first and second tunnel. However, any other suitable protocol may be used depending on the specific application. Especially the first tunnel may be tunnel

which may be set up and already exists for other reasons, as explained above.

The invention can be used in any kind of communication system SYS comprising a first network and a second network wherein said second network is an ad hoc network which is spontaneously or "ad hoc" formed as was explained above.

It should be noted that the invention comprises other embodiments and combinations which are not listed specifically above. For example, further embodiments may result from a combination of individual features and steps which have been separately described in the specification and the claims.

For example, another embodiment of the invention may comprise a computer program product, comprising code sections for respectively carrying out the functions of the respective units of the gateway GW in accordance with one or more of of the above embodiments and examples.

Another embodiment of the invention may comprise a computer program product, comprising code sections for respectively carrying out the functions of the respective units of the second terminal node MN in accordance with one or more of of the above embodiments and examples.

Finally, yet another embodiment of the invention may comprise a computer program product, comprising code sections for respectively carrying out the method steps of respective units of the gateway and/or the second terminal node, in accordance with one or more of the above embodiments and examples.

Furthermore, it should be noted that what was described above only designates the best mode of the invention as

currently known to the inventors and the invention can comprise other embodiments as well. Furthermore, other modifications and variations of the invention are covered by the attached claims.

Reference numerals in the claims serve clarification purposes and do not limit the scope of these claims.